Diet composition of common leopards in Bardia National Park and the adjacent buffer zones and habitat corridor in Nepal

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Preface

This thesis has been submitted as a partial fulfillment of requirement for Master of Applied Ecology and Agricultural Sciences, Hedmark University, Evenstad, Norway.

Here, I would like to show my deepest gratitude to my supervisor Associate Professor Morten Odden of Hedmark University, Evenstad, Norway, for his excellent supervision. I feel lucky myself to have opportunity to work on this very interesting topic. I really appreciate all his advices and support throughout the work. I would also like to thank Professor Per Wegge of the Norwegian University of Life Sciences, Ås, Norway, for his cooperation in my work.

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Abstract

The common Leopard (*Panthera pardus*) is the most widely distributed species among the large felids. It is a great challenge to manage their depredation on livestock at global level. In this study, I examined spatiotemporal patterns of leopard diet composition in Bardia National Park, Nepal, the buffer zones surrounding the park and a recently established habitat corridor that extends towards a protected area in India. Based on analyses of leopard scat contents, I investigated how the proportions of three main prey categories, i.e. wild ungulates, domestic animals and smaller wild prey, differed between the park, buffer zones and the corridor. I also investigated how diet composition had changed over time by comparing my data (from 2013) with scat content data that were collected during 2000, prior to the establishment of the corridor. Spatially, scats were distributed mainly along the border of the national park (28), the buffer zones (24), and in the corridor (21). Only two scats were found further than 500 m inside the park. Out of 63 scats with recognizable content (10 scats contained only grass, soil or bone fragments and were omitted from the analyses), 29 (46%) were from wild ungulates (26 chital (*Axis axis*) and 3 nilgai (*Boselaphus tragocamelus*)) and 12 (19%) contained smaller wild mammals and birds. Among these, 3 were rhesus monkey (*Macaca mulatta*) and 3 were langur (*Semnopithecus hector*). Twenty-two scats (35%) contained domestic animals, i.e. 14 goat, 5 pig and 3 sheep. Statistical analysis (G-test) showed no significant differences in diet composition between scats collected during 2013 within the national park and outside in the buffer zones and corridor. This was evident both when grouping the prey items into three categories (i.e. ungulates, domestic and other; G= 0.201, DF=2, P=0.905), and when grouping the prey into two categories (i.e. wild prey and domestic prey; G=0.191, DF=1, P=0.662). However, there was a significant difference in composition of scats collected in 2000 and 2013 when using two prey categories (Wild and domestic; G=3.976, DF=1, P=0.0462).Scat samples from 2013 contained 64% goat, 23% pig, 14% sheep and no calves, and these proportions were almost identical as reported losses among 161 interviewed households (i.e. 65% goat, 22% pig, 10% sheep and 3% calves. The similarity of the results indicate that the scat analyses were reliable, and also identify goats as the most commonly killed domestic prey. I suggest two explanations to the lack of difference in composition of scats collected inside and outside the national park. Firstly, the two parts of the study area were relatively small, and leopards may have moved between them. Secondly, scats found within the park were located near the park border, thereby suggesting that these leopards may have moved frequently outside to feed on domestic animals. The difference between scats collected in 2000 and 2013 was mainly due to an increase in consumption of domestic animals. This may indicate that leopards are more in contact with humans following the establishment of the habitat corridor. This study and other studies have shown that leopards are highly opportunistic animals that commonly consume domestic prey when they are available.

Hence, conservation efforts aimed at connecting protected areas should take into account that an increased distribution of wild carnivores is likely followed by elevated conflicts with humans.

1. Introduction and objectives

Leopards are the most widely distributed member of the wild felids occupying areas across sub-Saharan Africa, the Middle East and the Far East, northwards to Siberia and southwards to Sri Lanka and Malaysia (Fig 1, Nowell, Jackson 1996, Alderton 1993 & Uphyrkina et al. 2001). In Asia, their distribution is comparatively more restricted than in the east, central and southern Africa (Gavashelishvili, Lukarevskiy 2008, Nowell, Jackson 1996 & Nowak 1999). Despite of their wide distribution (Mills, Harvey 2001 & Alderton 1993), leopards are listed as Near Threatened on the IUCN Red List (Henschel *et al*. 2008).

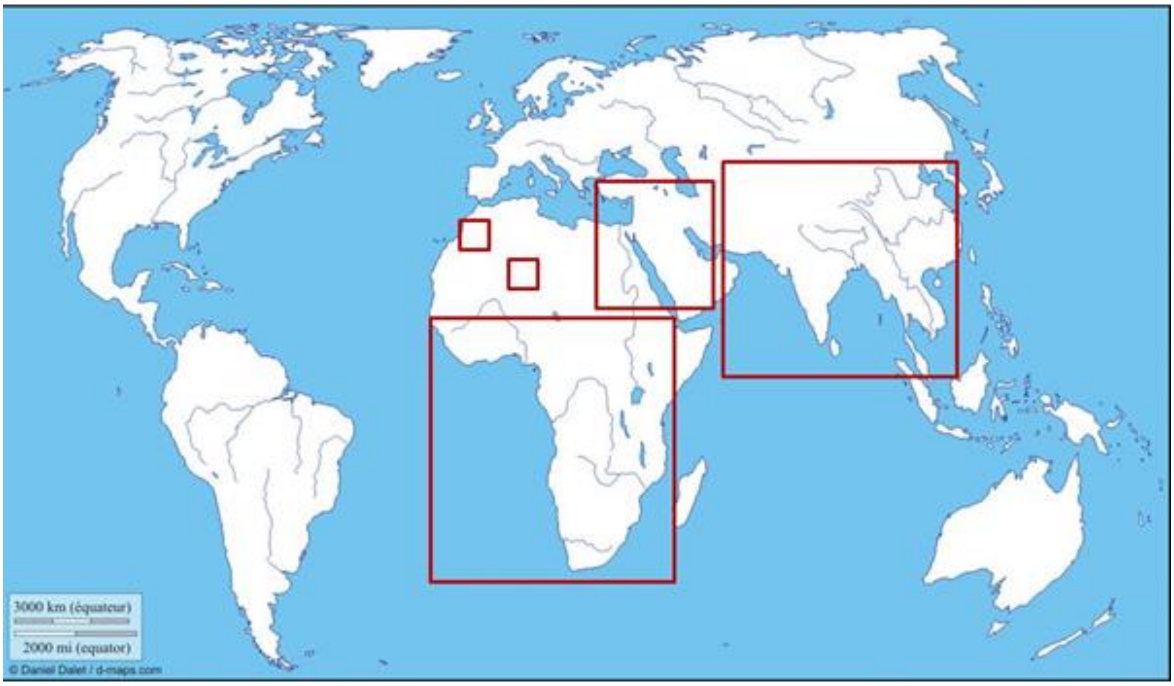

Fig1. Worldwide distribution of leopard (*Panthera pardus*). Adapted from www.d-maps.com, according to IUCN fact sheet (http://library.sandiegozoo.org/factsheets/leopard/leopard.html, retrieved at 29/07/2014).

The wide distribution of leopards reflects their adaptability to a wide variety of climates and habitats (Beer *et al* 2005 & Bailey 1993). Habitats range from tropical rainforest to arid savanna and from alpine mountains to the edges of urban areas (Nowell, Jackson 1996). Among these habitats, the riparian zone has the highest leopard density (Bailey 1993 & Maddox 2003). Furthermore, leopards opportunistically feed on a wide range of prey species (Mills, Harvey 2001). This broad diet includes ungulates such as chital (*Axis axis*), impala (*Aepyceros melampus*), bushbuck (*Tragelaphus scriptus*), common duiker (*Sylvicapra grimmia*), giraffe calves (*Giraffa* *camelopardalis*), eland antelope *(Taurotragus oryx)*, wild boar (*Sus scrofa*), and sambar (*Rusa unicolor*). Leopards may also feed on smaller animals such as langur (*Presbytis entellus*), hare (*Lepus nigricollis*), porcupine (*Hystrix indica*), small birds, rodents, arthropods or amphibians. Furthermore, their diet may also include domestic animals such as goats, pigs, buffalo calves and other livestock (Mills, Harvey 2001, Muckenhirn, Eisenberg 1973, Hayward *et al*. 2006, Schaller 1977, Ott *et al.* 2006, Mitchell *et al.* 1965, Hirst 1969, Kingdon 1977, Scheepers, Gilchrist 1991, Dominik 1988 & Daniel 1996).

In general, leopards are threatened in some areas because of sport hunting, habitat loss, prey depletion, diseases, trade in body parts and direct conflicts with humans (Sillero-Zubiri, Laurenson 2001, Martin, Meulenaer 1988 & Nowell, Jackson 1996). Proposed causes for human-carnivore conflict are depletion of the natural prey base, degradation or fragmentation of habitat, and/or man-made modification of the landscape resulting in suitable habitat for leopards (e.g., sugarcane, tea plantations, tall crops), and increase in human populations and local leopard populations resulting from successful conservation programs (Linnell *et al*. 2001 & Athreya *et al*. 2004).

Humans often consider large carnivores as a direct threat to their lives. The greatest source of human- carnivore conflict is, however, competition for resources, such as domestic animals, or wild prey species. Hence, human-carnivore conflict often implies a certain level of livestock depredation, especially in areas with intensive animal husbandry practices (Mizutani 1999 & Butler 2000). Globally this has become an increasing problem. These issues and conflicts are often destructive, costly and also not only chip away at effective conservation but also put off economic development, social equality and resource sustainability (Redpath *et al.*2013, Athreya *et al.* 2010, Treves, Karanth 2003 & Woodroffe *et. al* 2000). Typically, conservation actions, research and legislation focus mainly on protected areas with the aim of minimizing human settlements and agro-pastoral lands (Karanth, Gopal 2005 & Walston *et al*. 2010), but for conservation of these carnivores, one should identify the tolerance limit of carnivores in a wider range of landscapes which not only includes protected areas but also covers human and agricultural landscape (Sanderson *et al.* 2002 & Athreya *et al*. 2013).

The establishment of national parks and wildlife reserves in the productive lowland has mitigated loss and degradation of habitats, and during the last years, habitat corridors have been set up for linking protected areas in order to secure genetic viability of wildlife populations. In Nepal, the Terai Arc Landscape (TAL) program was initiated from 2001 with three main goals which are;

1. To restore connectivity among the 11 protected areas within TAL,
2. To increase the land base that supports the region's biodiversity, and

3. To provide increased ecological services by restoring the health and integrity of forest ecosystems.

The program was jointly implemented by the Department of Forest (DoF), the Department of National Park and Wildlife Conservation (DNPWC), the Ministry of Forest and Soil Conservation (MFSC) and World Wide Fund for Nature (WWF), Nepal in collaboration with local communities and Non-Governmental Organizations (NGOs). The Terai Arc Landscape extends from the Bagmati river in the east to the Mahakali river in the west (Fig 2).

The Khata corridor is a transboundary ecological zone between Bardia National Park, Nepal and Katarniaghat Wildlife Sanctuary, India covering a distance of 9 km. Recent monitoring programs conducted by DNPWC, the National Trust for Nature Conservation (NTNC) and World Wide Fund for Nature (WWF) have documented the presence of both tigers and leopards in the corridor. Furthermore, previous research conducted in Bardia have shown that the two species do coexist in the park, and that leopards tend to occupy the margins of tiger ranges, closer to human settlements (Odden,Wegge 2005, Wegge *et. al.* 2009 & Odden,Wegge 2009). It is of vital importance to gain further insight into the ecology of leopards both within the park and in the adjoining corridor in order to plan measures to mitigate the potential conflicts with humans that may follow an increased density and distribution of leopards.

In this study, I determined the diet of leopards in the Bardia National Park, Nepal, the adjoining Khata Corridor and Buffer Zones based on analyses of scats. I compared diet composition between areas of contrasting prey availability and human influence on the environment. Within the national park, wild ungulate densities are high and livestock grazing is prohibited (Wegge *et al.* 2009). Within the buffer zones and the Khata corridor, wild ungulate densities are lower and some controlled livestock grazing is allowed (Nagarkoti 2012). Hence, I predicted that scat samples collected in the national park contained larger proportions of wild ungulates, whereas scats from the buffer zones and the corridor contained a larger fraction of domestic animals. Furthermore, I compared the composition of scats collected in 2013 with a previous sample collected in the same area (except the corridor) in 2000 (Odden 2007), before the Khata corridor was established. This allowed me to investigate potential temporal changes in diet composition following the establishment of the corridor. I predicted a larger proportion of domestic animals in the scats from 2013 due to a higher interaction between livestock and leopards.

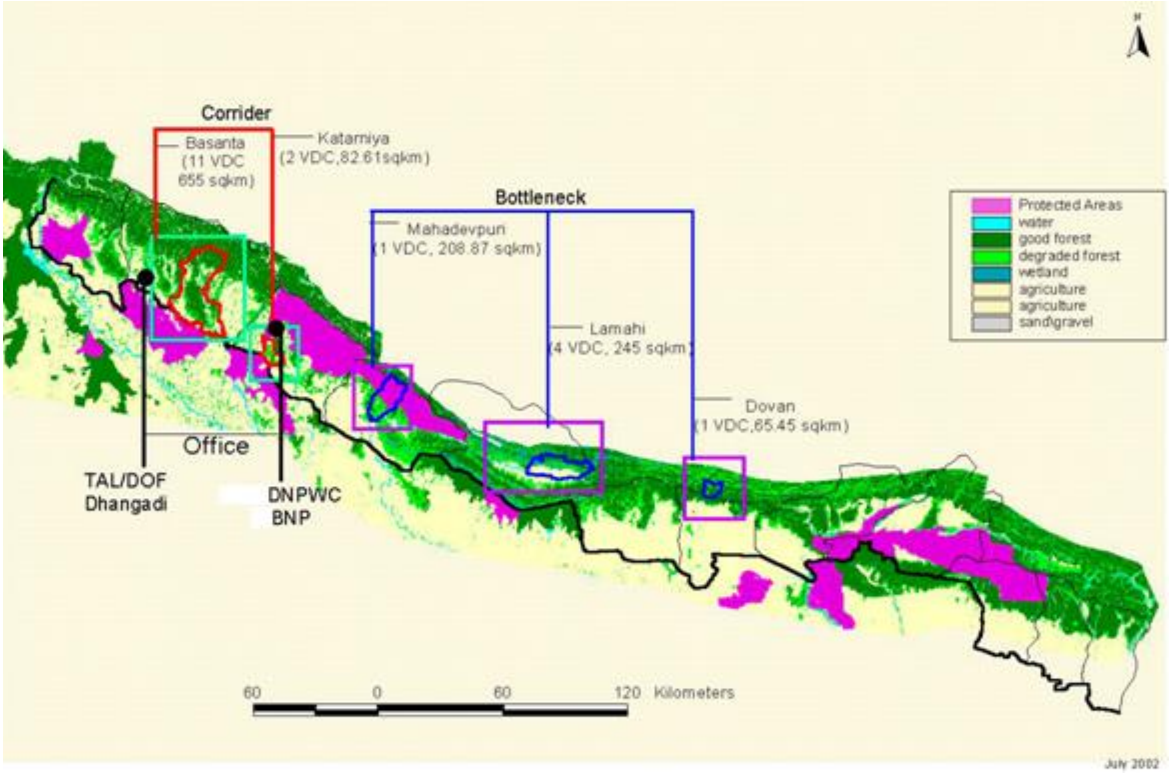

Fig 2. Corridors within Terai Arc Landscape (Source: TAL annual report 2002, WWF-Nepal).

2. Study area

The Bardia national park (BNP) is one of the 10 national parks in Nepal with an area of 968 km^2. It is situated in the mid- western Terai, east of the Karnali River. The park is bordered by the large Geruwa River in the west, the east-west highway in the north, and by human settlements and cultivated land in the east and south (Fig 3). The climate is subtropical monsoonal with heavy rainfall from July to September/October. Important plant species in the park include sal forest interspersed with patches of *Imperata cylindrica*, and riverine forest with tall grasses (Dinerstein 1979a & Sharma 1999).

More than 30 different mammals, over 230 species of birds and several species of snakes, lizards and fishes have been recorded in the park (Upreti 1994). Endangered animals found in the park are tiger (*Panthera tigris*), asian elephant (*Elephas maximus*), greater one –horned rhinoceros (*Rhinoceros unicornis*), swamp deer (*Cervus duvaucelii*), and black buck (*Antilope cervicapra*). Other endangered species are gharial (*Gavialis gangeticus*), marsh mugger (*Crocodylus palustris*) and Gangetic dolphin (*Platanista gangetica*). Endangered birds include Bengal florican (*Houbaropsis bengalensis*), lesser florican **(***Sypheotides indicus)* and sarus crane (*Antigone antigone*) (Upreti 1994). In parts of the park, ungulate prey density is very high i.e. > 200 animals per km^2, and common species are axis deer, hog deer (*Axis porcinus*), barking deer (*Muntiacus muntjak*), wild boar and barasingha (*Cervus duvauceli*) (Wegge *et al*. 2009). A large number of domestic animals were grazed within the park until late 1970s but since then livestock grazing has practically ceased (Tamang, Baral 2008).

In an extended area next to the park, referred to as buffer zone, local communities are allowed to legally extract forest products and graze their animals. The buffer zone of BNP has an area of 327 km^2 with 17 Village Development Committees (VDCs), 94 wards and 9528 households (HMG 1996) (Fig 3). A survey of three village development committees adjacent to the Bardia national park showed a serious problem of crop and livestock depredation in those areas (Studsrød, Wegge 1995). In the park, about 30-50% of the total received revenue is utilized for community development activities (HMG 1996). One of the most important activities is compensation for the loss of property due to wildlife, landslides or floods in the park land bordering rivers (HMG 1996).

The Khata corridor extends southwards from the western part of BNP with a length of 9 km and an area of 82.61 km^2 (Fig 2 & 3). This corridor connects the park with Katarniaghat Wildlife Sanctuary in India and it is dissected by the Geruwa and Orai rivers in the north-western part and by Babai river in the south-eastern part. Important plant associations and species include sal forest, riverine forest, khair (*Senegalia catechu*), sissoo (*Dalbergia sisoo*), tall grass flood plain, simal (*Bombax* *ceiba*), teak (*Tectona grandis*) and bushy pasture lands. Faunal composition includes rhino, asian elephant, tiger, leopard, large Indian civet (*Viverra zibetha*), small Indian civet (Viverricula indica), leopard cat (*Felis bengalensis*), jungle cat (*Felis chaus*), binturong (*Arctictis binturong*), wild boar, barking deer, chital, hog deer), nilgai (*Boselaphus tragocamelus*) , langur (*Semnopithecus hector*), and rabbit (Adhikari, Khadka 2009 & Yadav 2011). This corridor is habitat for 141 species of birds including globally threatened bird painted stork (*Mycteria leucocephala*) (Chaudhary *et al.* 2009). Nevertheless, a recent study found contrasting ungulate densities in the Khata corridor and the Bardia National Park (Nagarkoti 2012). Pellet counts revealed that the densities of chital and hog deer were approximately 10 times and 7 times higher in the park than in the corridor, respectively. Swamp deer and sambar deer were not found in the corridor, whereas the densities of wild boar and barking deer were quite similar between the two areas. The Khata corridor comprises two Village Development Committees (VDCs); Surya Patuwa and Dhodhari and surrounding settlements are Dalla, Naurangha, Bhajpur, Dandagaun, Patharbhoji, Manaughat. Communities of indigenous Tharus and hill migrants from Pyuthan, Jumla, Mugu and Kalikot inhabit the corridor and buffer zones. The current conservation issues and problems of the corridor are crop damage, livestock depredation, uncontrolled grazing, illegal felling, poaching and weed encroachment (Awasthi 2000).

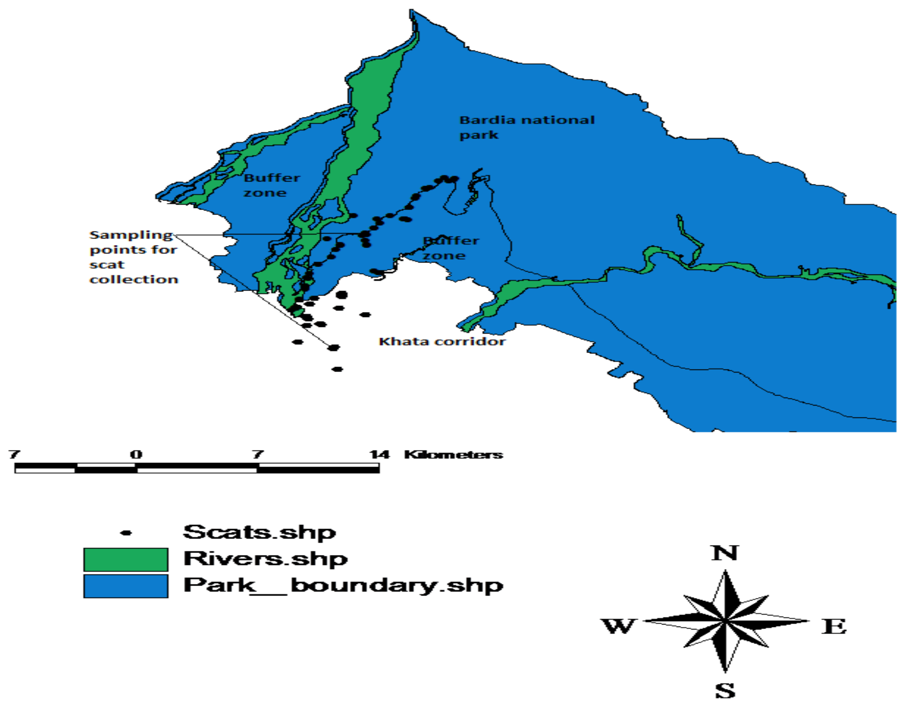

Fig 3. Bardia national bark, its buffer zones and Khata corridor with different sampling points.

3. Material and methods

3.1.Faeces / dung

Faeces represents a readily available and easily collected source of information. Differential distribution of dung enables the establishment of patterns of habitat use, and microscopical analysis of food remains in faecal matters allows for the reconstruction of animal diets. Dung is also commonly used to estimate population size and to distinguish sex and species of animals (Putman 1984). Dung residue also reveals the nutritional quality of dietary intake. Much of the materials in carnivore scats are readily identified macroscopically and there are many excellent guides to the identification of animal remains. Carnivore remains may contain bone with different shape and structure, different tooth pattern, hairs and feather patterning (Putman 1984).

3.2.Field sampling of predator scats

The southwestern part of the park and the surrounding buffer zones and the Khata corridor were divided into 41 different sampling blocks of approximately 4 km^2 each. Out of 41sampling blocks, 18 were in the park, 10 were in buffer zone and 13 were in the corridor. During study period, all blocks/grids were visited twice for scat sampling. Leopard scats were collected in a period from January to April 2013 by surveying roads and trails within the study area. Excess scats of each collection were removed from the sites to prevent repeated sampling. This sampling method is effective because leopards travel frequently along forest roads and trails where they defecate as a social communication mechanism (Smith, McDougal, Miquelle 1989 & Karanth, Sunquist 2000). The way of scat deposition of leopards is similar to that of tigers, but scats of leopards were discerned by their smaller size, with instantaneous examination of size and shape of associated tracks and scrape markings (Andheria *et al.* 2007). In addition, date, UTM coordinates and forest types were recorded. The relative age of every scat was determined on the basis of their odor. Scats with a strong odor were considered as fresh, scats with less odor were categorized as medium old and scats with no odor were categorized as old (Table 1).

Table 1. Number of located leopard scats in different parts of the study area, and their relative proportions categorized as old, medium and fresh.

	Total Scats	Age of scat	% Coverage
Park	28	Fresh	25
		Medium	7.14
		Old	67.86
Buffer zone	24	Fresh	29.17
		Medium	16.67
		Old	54.17
Corridor	21	Fresh	19.05
		Medium	9.52
		Old	71.43

3.3.Analyses of scat materials

A total of 73 scats were identified and collected during the sampling period. After collection, scats were sun dried for some days to avoid fungal growth. Next, scats were sealed in different envelopes and marked with an individual ID number. For diet analysis I followed a modified version of the point frame method originally developed by Chamrad & Box (1964), later modified by Ciucci *et al*. (2004). During the treatment, dried scats were first dissolved in water until they got wet. Secondly, they were sieved separately, and thirdly, they were transferred into a gridded tray where 50 different hairs were picked with tweezers from intersections in the grid. The hairs were examined under a dissecting microscope and identified by comparing them with sample slides of hair from the following species: chital / spotted deer, sambar, hog deer, nilgai / blue bulls (*Boselaphus tragocamelus*), muntjac / barking deer, common leopard, terai grey langur (*Semnopithecus hector*), barasingha/ swamp deers, golden jackal (*Canis aureus*), Rhesus Macaque (*Macaca mulatta*), domestic goat, asian elephant, sloth bear (*Melursus ursinus)* , Royal Bengal tiger, rabbit, domestic dog, domestic pig, domestic sheep, cow, buffallo, yak (*Bos sp*.) and gaur (*Bos gaurus gaurus*) . I also used an identification key book prepared by Koppikar and Sabnis (1976).

The relative abundance of prey species in the scats was calculated by using the equation; $F_i = (n_i/N)100$ (Pikonov, Korkishko 1992; Karanth, Sunquist 1995; Mizutani 1999 & Ramakrishnan *et al.*1999), where F_i is the prey frequency of occurrence in the scat samples (the proportion (%) of scats containing a given prey item), n_i is the number of scats where a given i^{th} prey species residue occurs and N is the total number of all scat samples (Table 4).

I used log-linear likelihood models (G-tests) on contingency tables (Reynolds, Aebischer 1991) in order to test for differences in overall diet composition between sampling periods. For this, food items were grouped into three categories, i.e. “wild ungulates” (e.g. chital and nilgai), “domestic” (Goat, Pig and Sheep) and “other” (Rhesus monkey, Langur monkey, and other small wild mammals and birds). Relative abundances of prey were converted into “whole scat equivalents” (WSE) following the method described by Angerbjörn et al. (1999). This method allows for direct comparisons of proportions of ingested of different food items in scats without altering the total sample size. For instance, if 10 scats contained proportions of 50% wild ungulates and 50% domestic prey they would be converted to 5 scats of 100% wild ungulates and 5 scats of 100% domestic prey.

In order to investigate differences in leopard diet following the establishment of the Katha corridor, I have used secondary leopard scat content data collected by Odden M. in year 2000 (Odden M. 2007). This material consisted of 96 scats that were collected and analysed using a similar method as I did for the samples collected in 2013.

3.4.Leopard-human conflict

For investigating loss of domestic animals due to leopard depredation, I compared my results from the scat analyses with interview data that were obtained from the NTNC annual report of year 2011/2012. For human-wildlife conflict monitoring and assessment, NTNC, in collaboration with the Awely France, conducted interviews with local households from February 2011 to June 2012. During this period, two people recorded all cases of livestock depredation that had occurred the preceding year in nine village development committees of the buffer zones surrounding the Bardia National Park. Households affected by leopards were found in Thakurdwara, Suryapatuwa and Shivapur. A total of 161 households that had lost livestock were interviewed.

4. Results

4.1. Spatial distribution of scats

During the scat survey, intensely used trails and fresh scats were found more close to human habitation. Among all the 73 scat samples, 28 (i.e. 38% of scats) were found along the border of the national park, 24 (33%) were found in the buffer zones and 21 (29%) were in the Khata corridor. The numbers of blocks where I searched for scats were 19 (46% of blocks) inside the park, 9 (22%) within the buffer zones and 13 (32%) in the Khata corridor. Hence, a smaller proportion of scats were found within the park than expected if scats were distributed equally among sampling blocks. However, the difference between observed distributions of scats inside (28 samples) and outside (45 samples) the national park and the expected distribution (with distributions reflecting sampling effort, i.e. 32 samples inside the park and 41 samples outside the park) was not significant (G-test; $G = 1.86$, $DF = 1$, $P = 0.173$). Almost all the scat samples from the park were found close to the park border, i.e. only 2 were more than 500 m inside the park. Out of 41different sampling blocks, only 14 sampling blocks were found to have scats (Table 2).

Table 2. Contents of leopard scats found in 14 different sampling blocks within Bardia national park, surrounding buffer zones and the Khata corridor. An additional 27 surveyed blocks did not contain leopard scats.

Sampling Blocks	**Location**	**Ungulate**		**Domestic**			**Primate**		**Smaller wild animals + birds**	**Plant/ grass remain**	**Soil+ bone remain**	**Unknown**	**Total**
		Chital	**Nilgai**	**Goat**	**Pig**	**Sheep**	**Rhesu**	**Langu**					
43	Park	1		1	1	1			1			1	6
56	Park	2					1						3
67	Park				1					1	1		3
68	Buffer	6						1		1			8
79	Park	2		1					1				4
80	Buffer	2			1	1		2					6
93	Park		1	2	1						1		5
108	Buffer			1					1				2
124	Buffer	3	1	3		1	1		1	2			12
125	Corridor	3			1				1				5
141	Corridor	6	1	1						1			9
159	Corridor			1									1
B	Corridor			3					1	2			6
E	Buffer	1		1			1						3
Total		26	3	14	5	3	3	3	6	7	2	1	73

Note: The sampling blocks where I did not find scats were 32 (Park), 33 (Park), 34 (Park), 39 (Park), 40 (Park), 41 (Park), 42(Park), 44 (Park), 45 (Park), 54 (Park), 55 (Park), 65 (Park), 66 (Park), 78 (Park), 92 (Buffer), 107 (Buffer), 123(Buffer), 142 (Corridor), 160(Corridor), 177(Corridor), 178(Corridor), 179 (Corridor), 194 (Corridor), 195(Corridor), 208 (Corridor), A (Corridor), and D (Buffer).These are not included in the table 2.

( )*location

4.2.Overall diet composition

Among the total of 73 collected scats, eight scats contained only plant material or soil, whereas one scat contained only unrecognizable bone fragments and one contained material that I was unable to identify. These scats were omitted from the further analyses, thus rendering a total sample size of 63 scats. All collected scats contained only one identified prey species each. Among the 63scats used in the analyses, 29 (46%) contained hair from wild ungulates; three of these scats contained nilgai and 26 contained chital. Twelve scats (19%) contained hair from smaller mammals and birds; three of rhesus monkey, three of langur monkey and six from birds. Twenty-two scats (35%) contained hair from domestic animals, including three from sheep, five from pigs and 14 from goats Interviews of 161 households that had lost livestock due to leopard attacks in year 2012 recorded 116 killed goats, 38 pigs, 17 sheep and 6 calves. The relative proportions of different domestic animal species was almost identical in the scat content data (goats = 64%, pigs = 23%, sheep = 14%, calves = 0%) and in the data based on interviews (goats = 65%, pigs = 22%, sheep = 10%, calves = 3%).

Table 3. Occurrences of prey species (based on hair and other food) in *Panthera pardus* scat (n-73).

Prey species	**Park**	**Buffer zone**	**Corridor**	**Total Number**	**Relative abundance (%)**
Chital	8	11	7	26	35.62
Nilgai	2	0	1	3	4.11
Rhesus	1	2	0	3	4.11
Langur	2	1	0	3	4.11
Domestic Pig	3	1	1	5	6.85
Domestic Goat	4	4	6	14	19.18
Domestic Sheep	1	2	0	3	4.11
Birds	2	2	2	6	8.22
Plant/soil remains	3	1	4	8	10.96
Bone remains	1	0	0	1	1.37
Unknown	1	0	0	1	1.37
	28	**24**	**21**	**73**	100

4.3.Spatial pattern in diet composition

Scats containing domestic animals were found in all parts of the study area, i.e. in the national park, buffer zones and the Khata corridor, and the frequency of occurrence of this prey category was highest in the park, and lowest in the buffer zone (Fig 4). The proportion of wild ungulates was highest in the corridor and lowest in the park. However, there was no significant difference between the three areas in the frequencies of occurrence (FO) of the three food categories (G-test; G = 2.99, DF = 4, P = 0.599). Furthermore, there was no significant difference when comparing the FOs of samples from inside and outside the national park (G = 1.56, DF = 2, P = 0.457). Lastly, I grouped the samples into two categories, i.e. domestic and wild animals, and tested whether the FOs of these two categories differed between samples from inside and outside the park, but there was no significant difference (G = 1.21, DF = 1, P = 0.271).

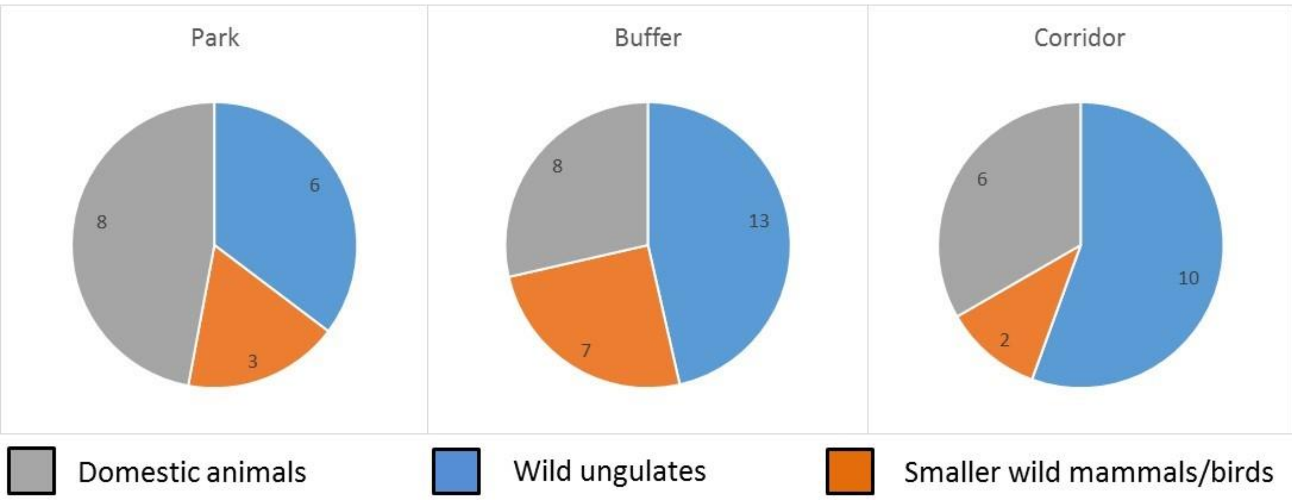

Fig 4. Contents of leopard scats collected in Bardia national park (Park), surrounding buffer zones (Buffer) and the adjoining Khata corridor (Corridor). The charts display relative proportions of three food categories and the numbers of scats containing these food items.

4.4.Temporal difference in diet composition

The diet composition between two years 2000 and 2013 was compared first with three different categories (wild ungulates, smaller wild mammals/birds and domestic animals, Fig 5) and second with two different categories (wild animals and domestic animals). There was a significant difference in diet composition between the two years when using two food categories (G = 3.83, DF = 1, P = 0.050), but not when using three food categories (G = 3.94, DF = 2, P = 0.139). The main difference between the two years of sampling was a larger proportion of domestic animals in the scats from 2013.

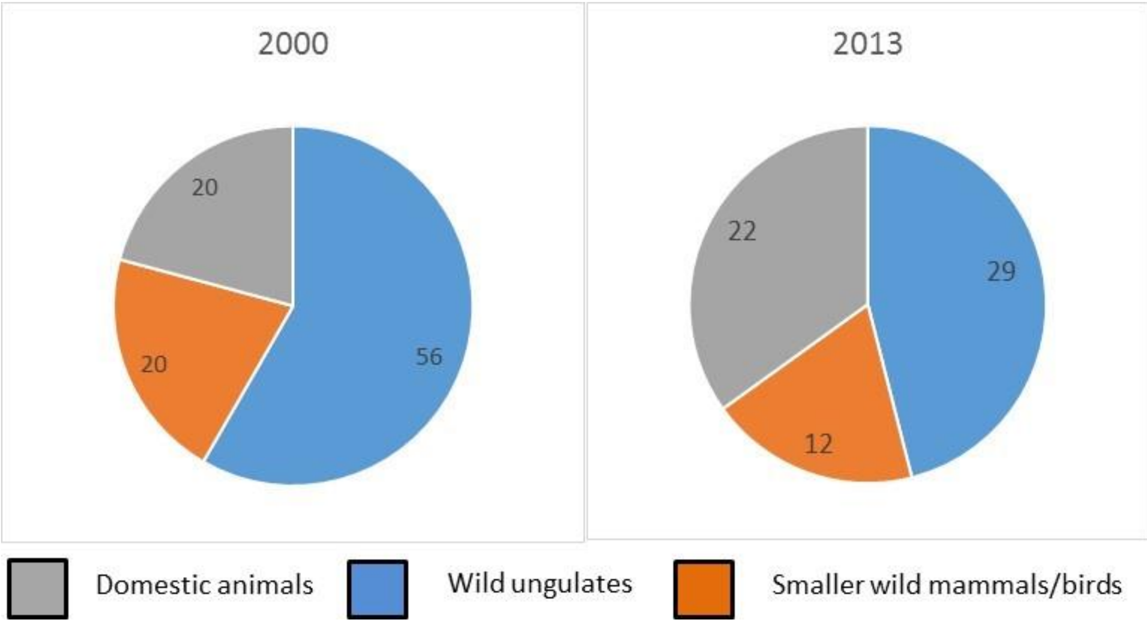

Fig 5. Contents of leopard scats collected in Bardia national park in year 2000 and within the park and surrounding areas in 2013. The charts display relative proportions of three food categories and the numbers of scats containing these food items.

5. Discussion and conclusion

The scats were found to be distributed mainly along the park border, in the corridor and buffer zone. However, very few scats were found further inside the park than 500 m. Also, there were very few pugmarks or scrape signs in this part of the study area, but I did notice many tiger pugmarks. Odden, Wegge and Fredriksen (2010) compared the distribution of tiger and leopard signs (scats, scrape marks and pug marks) previously in the same area, and reported that leopards were mainly distributed along the park border at the margins of tiger's territories. This pattern was assumed to be caused by interference competition leading to avoidance of tigers by leopards. Avoidance of tigers may thus explain the distribution of leopards' scats along border of the park in my study.

A recent study of prey abundance in Bardia national park and the Khata corridor revealed pronounced differences between these areas (Nagarkoti 2012). Firstly, pellet groups of chital were few in the corridor (4.6% of sample plots) compared to the park (45.7%), whereas wild boar pellets were higher in the corridor (35.6%) than in the park (22.8%). Secondly, Hog deer was seven times higher in the park than in the corridor while livestock was abundant in the corridor. Despite the pronounced difference in prey distribution, I found no significant differences in composition of scats collected in different parts of the study area. A previous telemetry study of leopards in Bardia showed that 2 males used ca 50 km^2 home ranges, whereas one females used 17 km^2 (Odden & Wegge 2005). Hence, the leopards may traverse areas large enough to include both parts of the park, the corridor and the buffer zones. Therefore, the remains of a prey killed in the park may end up in the corridor or buffer zones. Furthermore, leopard scats from the park were almost solely located close to the park border. Accordingly, the leopards leaving these scats were probably much exposed to humans and livestock and using areas that were somewhat similar in prey availability as in the corridor and buffer zones.

Although the leopards' main prey was chital, they consumed a large proportion of domestic prey. This pattern may be caused by leopards being distributed near human settlements (Karanth, Stith 1999) due to their interference competition with tiger inside the park (Odden et al. 2010). This might propel domestic animals to become a dominant food source for leopards (Edgaonkar, Chellam 2002), resulting in elevated conflicts with humans (Athreya 2006). Still, the large proportion of domestic animals in the leopard diet is surprising when considering the high density of wild prey species. Although domestic animals are easy to kill, the close association with humans should involve risks of retaliations. Odden & Wegge 2005 found that killing of domestic animals was more common among males than among females and suggested that this difference was due to a “high risk-high gain” strategy among male leopards. Accordingly, domestic prey might be easily available resource that is dangerous to utilize due to a higher mortality risk.

Goats were the most commonly consumed species of domestic animals, followed by pigs, sheep and calves and, interestingly, the relative proportions were almost identical as reported losses among interviewed households. The similarity of the two sources of data indicates that the scat analyses provided reliable results. The results also identify the protection of goats as an important proactive conflict mitigation measure. I also found that the proportion of domestic animals in the leopard scats was higher in the samples collected in 2013 than in samples collected in 2000. Hence, the utilisation of domestic animals seems to have increased over time. The cause of this increase is probably related to the fact that leopards are more frequently coming into contact with humans and their livestock following the establishment of the Khata corridor. Given the opportunistic foraging behaviour of leopards, an increase in the availability of any food source could possibly lead to diet changes. Accordingly, it is important to take into account that successful establishments of habitat corridors may lead to movement of leopards into areas with a higher availability of domestic animals, and that this may elevate human-leopard conflicts. It is inevitable that livestock depredation by leopards create hostile attitudes among local people. Hence, there is a great need to develop reliable mitigation measures when planning conservation efforts, such as establishing corridors. In Bardia, current conflict mitigation consists of corralling and stall feeding under the support of the TAL program (HMG 1996, WWF Annual report 2002). To maintain a sustainable population of leopards without livestock depredation is a challenging task in an area like Bardia national park where domestic animals are consumed to a great extent even though natural prey is abundant. Thus long term conservation of leopards in such areas requires measures which promote natural prey for leopards while keeping livestock depredation at a minimum. Community involvement in carnivore conservation approaches is also of great importance to solve this problem. Increased community tolerance may be facilitated by improving economic benefits to the community through compensation of losses and promoting ecotourism, and by involving local people in research and conservation activities.

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